An Empirical Investigation of Live Hog Demand

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Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management

Chicago, Illinois, April 17-18, 2000

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An inverse live hog demand model was estimated to analyze claims that the live hog own quantity demand flexibility's magnitude has increased in recent years. A second objective of this research was to estimate the impact changes in processing capacity utilization rates have on live hog prices. Iowa - Southern Minnesota barrow and gilt price was modeled as a function of average daily hog slaughter, a processing capacity utilization ratio, an index of processing and marketing costs, a retail demand shift index, pork cold storage stocks, and monthly binary variables. Results indicate that in recent years live hog prices have become more responsive to changes in hog slaughter. Additionally, changes in processing capacity utilization rates, at times, also have a relatively large impact on live hog prices. Finally, when the large live hog price decline that occurred during the fall of 1998 *is examined, model results indicate that the accumulation of large pork cold storage stocks, the sharp increase in processor's capacity utilization rates, an increase in average dressed weight, and the increase in average daily hog slaughter all had a large negative effect on live hog prices*.

Keywords: Live Hog Demand, Structural Change, Capacity Utilization,

Introduction

During the fourth quarter of 1998 nominal live hog prices in the Iowa - Southern Minnesota market averaged $19.67 per cwt., the lowest quarterly price average since the early 1970s (LMIC). The decline in daily prices was even more dramatic as cash prices briefly dipped below $10 per cwt. during December 1998 (figure 1). The dramatic price decline led to large equity losses on the part of U.S. pork producers which, in turn, led the National Pork Producers Council (NPPC) to propose an "Action Plan" during summer 1999 which requested government intervention in the form of pork purchases and a subsidy to launch a new pork processing plant (National Pork Producers Council). Although fall 1998s large price decline was attributed primarily to a large increase in domestic hog slaughter and pork production (U.S. Department of Agriculture), two factors separated it from previous hog market price declines. First, it was larger than expected based upon historical hog market supply and demand relationships and, second, the price decline was much more severe at the live hog market level than at the wholesale level. The objectives of this research are to estimate a live hog demand model, determine the impact of utilization capacity, and determine whether the live hog price flexibility has changed.

The magnitude of the live hog price decline relative to the production increase led to speculation that live hog demand has become more inelastic (figure 1). In the most recent study focused on farm level demand, Wohlgenant (1989) concluded the own-quantity farm-level hog price flexibility was negative 2.07. During the fourth quarter of 1998, pork production rose 9.9 percent above the fourth quarter of 1997. Applying Wohlgenant's results to 1998 data implies that a 20 to 21 percent live hog price decline was expected. Instead, Iowa- Southern Minnesota live hog prices actually declined 55 percent. Although competing meat supplies such as chicken and beef also increased during this time frame, the meat supply increases were not large enough to explain the large farm level price decline. Based upon non-parametric analysis, Plain and Grimes concluded that the own-quantity farm-level hog price flexibility changed from negative 2 prior to fall 1998 to negative 5 during the fall of 1998. However, this conclusion has not been substantiated with rigorous parametric research.

Several possible explanations for the shift in hog price flexibility have been postulated. The U.S. pork industry has undergone considerable structural change over the last two decades. Real processor margins have declined substantially over this period (USDA, ERS) and pork processing capacity utilization levels have increased (National Pork Producers Council). In response to tighter pork processing margins and the shift in capacity utilization levels, packers may have become more price responsive to changes in slaughter hog supplies, i.e., more willing to pay higher prices when plants are operating below capacity and more inclined to pay sharply lower prices when operating above normal capacity. Also, hog marketing contract usage has increased considerably, especially in the 1990s. Very few hogs marketed in 1980 were sold under some type of marketing agreement (Grimes). Surveys by Grimes and Lawrence and Grimes and Meyer in 1997 and 2000 indicated that the percentage of hogs marketed under some type of marketing agreement increased from 56% in 1997 to nearly 75% in 2000. The rise in hog contracting could be important because when packers are committed to purchasing a large proportion of their hogs under contract, during times it could result in more variable prices for the remaining hogs sold in the open market.

At the same time live hog prices fell 55 percent below 1997s fourth quarter average, USDAs estimate of the pork cutout, i.e., wholesale, value declined just 32 percent. Although it's not unusual for wholesale and live market price changes to differ, the large discrepancy between the live and wholesale pork price changes was surprising. As a result, industry participants began to examine hog slaughter capacity to determine whether a lack of processing capacity might have been responsible for the difference in price response at the wholesale pork and live hog market levels.

The pork processing sector has changed appreciably in recent years. Reduced profitability in the pork processing sector led to many pork plant closures while other firms expanded to take advantage of economies of size.[1] For example, during 1997 pork plants closed in Council Bluffs, Iowa, Worthington, Indiana, and Moultrie, Georgia, and IBP switched from a double to a single shift in its Columbus Junction, Iowa, plant, all of which reduced hog processing capacity by 23,400 hogs per day (Luby). Moreover, during summer 1998 Thorn Apple Valley opted to close its Michigan slaughter facility which also reduced the industry's slaughter capacity, just before hog supplies increased sharply in fall 1998 (Luby). However, IBP in Logansport, IN, went to a double shift just prior to this period (NPPC). Data from NPPC indicates that estimated normal industry slaughter capacity between February 1998 and February 1999 declined from 417 thousand head per day to 381 thousand head per day. But, federally inspected hog slaughter data from November and December indicates daily hog slaughter volume reached a peak of 415,548 thousand head per day, suggesting the industry exceeded its

[1]Expansion may not necessarily be through capital investment. Expansion could occur through the addition of an extra work shift to the plant schedule or faster chain speeds.

normal daily slaughter capacity by increasing both the number of hours worked and weekend slaughter levels. Thus, it appears that a shortfall of processing capacity during fall 1998 might have contributed to the live hog price decline as processors continually reduced their bids for hogs while plants were operating above normal capacity levels.

If the hog price flexibility has increased (measured in absolute value), as hypothesized, it has important risk management implications for hog producers, processors, and retailers. Moreover, policy makers would also benefit from an improved understanding of hog price responsiveness to supply changes. If processing capacity utilization has a significant impact on live hog prices, hog producers and processors would benefit from an improved understanding of this relationship as they make future production plans and consider whether or not to expand slaughter and processing capacity. As a result, there is a need for improved measurement of the impacts that specific factors, such as pork production and pork plant capacity utilization, have on live hog price. The results of this study can be used by swine industry decision makers and poly makers to better make decisions regarding the future of the swine industry.

Previous Research

Most previous studies analyzing factors affecting demand for livestock commodities have focused on structural changes in retail demand with an emphasis on shifts in consumer preferences (McGuirk et al.; Moschini and Meilke; Tomek). There have been, however, a few studies evaluating farm level demand for hogs. Hayenga and Hacklander (1970) estimated an inverse live hog demand model. They specified a model where live hog price was hypothesized to be a function of hog production, cattle production, cold storage stocks lagged one month, the change in cold storage stocks between the current month and previous month, per capita income, and seasonal shift variables. Results from the empirical model estimated by Hayenga and Hacklander indicated a one million pound increase in average daily production decreased live hog price by $0.769/cwt. A one million pound increase in cold storage stocks one month lagged decreased live hog price by $0.023/cwt. Hayenga and Hacklanger hypothesized that the between month change in cold storage might be endogenous. That is, a low live hog price (highly correlated with the wholesale price) will cause storage speculation in anticipation of future higher prices. As a result, they estimated a change in pork cold storage stocks separately and found a one dollar increase in live hog price was associated with a between month decline in cold storage stocks of 2.29 million pounds.

Wohlgenant (1989), in one of the few studies in the last fifteen years that focused on farm level demand, estimated the farm level flexibility for pork by regressing farm level pork quantity, an index of marketing costs and a retail demand shifter on farm level price. He concluded that the own quantity farm level hog price flexibility was negative 2.07. However, the data in Wohlgenant's study only included data through 1985. Given the structural change in the swine industry, an updated analysis of live hog demanded is warranted.

Recent research by Brown and Spivey, Salin, and Anderson investigated the impact of processing capacity on live hog price. Analyzing weekly data from 1991 through 1999 and using Saturday slaughter as a proxy for processing capacity constraints, Brown concluded that had processing capacity not been limiting, the fall 1998 average live hog price would have been \$3.84/cwt. to \$5.76/cwt. higher than the actual market price. Spivey, Saline, and Anderson estimated live hog demand and pork cutout demand models using weekly data from 1990 through 1999 to investigate the impact of slaughter capacity on price. Their models specified live hog price and weekly cutout value as a function of weekly slaughter and a capacity measurement variable. Spivey, Saline, and Anderson used three different proxies for a processing capacity constraint variable. The three different proxies were a 0 or 1 binary variable when weekend slaughter exceeded 160,000 head for three consecutive weekends; weekend slaughter; and the ratio of weekend slaughter to slaughter during a 5-day work week. For the model using the ratio of weekend slaughter to slaughter during a 5-day work week, their results indicated that a one percentage point increase in Saturday hog slaughter, as constructed in their study, decreased live hog price by \$11.63/cwt. and increased the wholesale cutout value by \$10.58/cwt. This research improves on these studies by analyzing a longer time period (1980 to 1999) and adding other explanatory variables to the live hog price demand model that are hypothesized to impact live hog price. Omission of these factors in previous research may have produced biased parameter estimates due to model mis-specification.

Empirical Model

Tomek noted that changes in farm-level derived demand for agricultural commodities are a function of changes in retail-level demand, marketing, and processing costs. Building on Tomek's basic outline of a farm-level derived demand model and previous research by Brown; Spivey, Saline, and Anderson; and Wohlgenant, an inverse farm-level demand model for pork is specified in this study. The regression model is estimated using monthly data from 1981 to 1999. Variables are chosen so the model captures the impact of changes in processing capacity relative to industry size using two alternative specifications of a proxy variable designed to measure processing capacity utilization. The empirical model to be estimated is:

Iowa - Southern Minnesota Barrow & Gilt Cash Price$_t$ =
(1) *f*(Average daily hog slaughter$_t$, Average dressed weight$_t$, Processing utilization to capacity ratio$_t$, Index of processing and marketing costs$_t$, Retail demand shift index$_t$, Cold storage stocks$_t$, Seasonality$_t$).

Variable definitions and the expected impact on live hog price from a unit increase in the relevant explanatory variables are listed in table 1. The subscript *t* refers to month (t = January 1981 to December 1999). The dependent variable is the monthly average of the daily Iowa – Southern Minnesota Barrow & Gilt prices reported by USDA's Agricultural Marketing Service.

Production was decomposed into head slaughtered and dressed weight. Making comparisons between this study and previous studies may be difficult because most previous analyses have used production alone. Average daily slaughter is included in the model to represent packer demand for hogs. A high correlation exists between slaughter and production; yet, packer demand is partly based on the availability of shackle-space. All other factors being equal, an increase in average daily slaughter is expected to lead to lower live hog prices. An increase in average dressed weight is also expected to cause live hog price to decline.

Several methods have been employed to estimate processors capacity utilization. Studies by Barkley and Schroeder; and Ward, Koontz, Schroeder, and Barkley used proprietary cattle processing data to construct a capacity utilization variable. They employed the twelve month lag of the ratio of cattle marketed during a period to plant capacity. However, lack of data on the pork industry's processing capacity over the entire study period renders this measure of capacity utilization useless as processors commonly entered and exited the industry. Schroeder and Mintert used the ratio of current month slaughter to the maximum month slaughter during the previous twelve months in investing factors affecting pork processing margins. Other studies have specified capacity utilization as an overflow variable using Saturday slaughter (Brown; Spivey, Saline, and Anderson). Generally, a typical hog processing plant operates two eight-hour kill shifts daily followed by an 8 hour clean-up shift each day. Thus, to expand plant capacity a weekend kill is required.

Brown used a binary variable set equal to one when Saturday slaughter exceeded 160,000 head during three consecutive weeks. Spivey, Saline, and Anderson used three separate variable specifications of Saturday slaughter as a proxy for utilization to capacity. However, there is a fundamental problem with such a methodology. Beginning in the early 1980s and ending in the middle 1990s, IBP implemented a Tuesday through Saturday processing week to reduce the costs of carrying hogs over the weekend.[2] As a result, IBP's overflow day was Monday, not Saturday. Thus, using Saturday slaughter as a proxy for processor utilization capacity may be flawed.

Two separate variable specifications are used in this study as a proxy for capacity utilization. The first variable is the ratio of average daily slaughter in the current month to maximum daily slaughter during the previous twelve months (denoted model a). The second variable is specified as the ratio of the summation of Saturday and Monday slaughter to the twelve month lag maximum month Saturday plus Monday slaughter during the quarter relative to the month in the numerator (denoted model b). This adjustment was made to account for the potential change in processing plant operation in the short run in response to production seasonality. Both capacity utilization variable specifications account for the seasonality in pork production.

Typically processing plants minimize costs when operating at capacity (Ward). When slaughter is below capacity inputs are not used optimally, and when slaughter is above capacity additional costs are incurred in paying overtime labor. Thus, the relationship between the utilization to capacity variable and live hog price is expected to be non-linear. However, appropriately specifying this variable is difficult because the pork processing industry has undergone considerable change over the period of this study. To account for the differences in the impact of processing capacity utilization on live hog price over time and for varied levels of slaughter a Flexible Least Squares estimator is used to determine the change in magnitude of the

[2] IBP ended the Tuesday through Saturday work week during the middle of 1995 likely because labor costs of operating an irregular weekly schedule exceeded the costs of carrying hogs over the weekend.

coefficient. The Flexible Least Squares estimator is discussed in more detail at the end of this section.

Wohlgenant found that an increase in processing and marketing costs (measured by an index of food marketing costs) caused live animal price to decline. This is easily explained because, in the short run, hog supply is very inelastic. Therefore, short run increases in marketing costs would be passed on to hog sellers via live hog price reductions. As a result, live hog prices are expected to decrease when the marketing cost index increases.

A retail demand shift index is included in the inverse live hog demand model because the demand for live hogs is derived from consumer demand for retail pork. The retail demand shift index proposed in the current study follows Wohlgenant. The retail demand shift index is the summation of cross-elasticities of demand for retail good *j*, with respect to pork, multiplied by the retail price of good *j*, plus the income elasticity of pork multiplied by the sum of per capita income and population.[3] Cross-price and income elasticities were taken from McGuirk et al. Following from Wohlgenant, an increase in the retail demand shift index is expected to increase the live hog price.

The ratio of current month cold storage stocks to the twelve month lagged cold storage stocks was included in the inverse live hog demand model to determine the impact of cold storage constraints on price. An increase in cold storage stocks indicates current period production is larger than consumption. The ratio was used to account for seasonality in cold storage stocks. Schroeder and Mintert found that an increase in cold storage stocks increased pork processing margins. Therefore, an increase in cold storage stocks is expected to lead to a live hog price decline.

Seasonal dummy variables are specified as 0 or 1 binary variables where January is the default month. Seasonal dummy variables were included in the model to account for seasonality in hog production and consumer purchasing. The impact of the seasonal binary variable on price is expected to vary by month.

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[3]Following from Wohlgenant, a slight variation, i.e., the model in the current study was not specified in logrithmic form, of his notational form of the retail shift index ($Z_{pork,t}$) is used for the current study is:

$$Z_{pork,t} = \exp(\sum_{j \neq i} e_{pork,j} \log(P_{jt}) + e_{pork,y} \log(Y_t) + \log POP_t),$$

where $e_{pork,j}$ is the cross price elasticity of meat type j with respect to pork, P_{jt} is the price of meat type j at time t, $e_{pork,y}$ is the income elasticity of pork, Y_t is per capita disposable income, and POP_t is population.

Evaluating a Change in Live Hog Demand

Model stability, i.e., parameter stability, is of interest when estimating models where there has been considerable structural change in the industry being investigated. For the current study, a change in live hog demand is analyzed and tested using parametric analysis. Tests of model stability have typically been the CUSUM, CUSUM squared, or Log Ratio test statistic; however, using such test statistics does not address the issue of a change in the pork price flexibility magnitude, unless the data-set is partitioned and models re-estimated. The test of model stability used here is the Flexible Least Squares (FLS) estimator, introduced by Tesfatsion and Veitch. FLS is used to graphically depict how the pork price flexibility and processing capacity utilization estimates change over time. This graphical representation is useful for making inferences that match a change in demand to a structural change.

The FLS estimator is described briefly here. Assume a simplified inverse live hog demand model of the form:

(2) $$P_t = \beta_t Q_{pork} + \varepsilon_t ,$$

where P_t is the live hog price at time t (t = 1, . . ., T), Q_{pork} is the demand for live hogs at time t, and g_t is an *iid* ~ N(0,1) random error vector. The coefficient on pork demand ($\$_t$) is a 1 x T vector of a time varying parameter estimate. The FLS estimator minimizes the loss function from equation 2 as:

(3) $$\sum_{t=1}^{T}(P_t - b_t Q_{pork,t}) + l \sum_{t=1}^{T}(b_{t+1} - b_t)\ D\ (b_{t+1} - b_t) .$$

where 8 is a chosen constant greater than zero, and D is a K x K fixed matrix chosen to account for the difference in scaling between regressors. The first term is the sum of squared errors. The second term is the sum of squared parameter variations over time. The matrix D is specified as a diagonal matrix with diagonal elements $d_{ii} = \sum_{t=1}^{T} x_{ti}^{2} / T$ (Tesfatsion and Veitch, and Lutkepohl).

Data

Summary statistics of data used in the estimation of the inverse hog demand model are listed in table 2. All series are monthly data from January 1981 through December 1999. The monthly live hog price paid to producers is the Iowa - Southern Minnesota Barrow & Gilt price. Monthly values were calculated by averaging daily prices reported by the USDA. Beginning in April 1999 the price quote for the Iowa - Southern Minnesota Barrow & Gilt price changed from a 48% lean hog to a 52% lean hog. Therefore, for the April to December 1999 period an Iowa-Southern Minnesota barrow and gilt price was estimated using a lagged Iowa - Southern Minnesota price and the USDA terminal market price during the current month. The average cash price was $46.08/cwt. with a range of $13.92/cwt. to $63.44/cwt. The price series was deflated by the Consumer Price Index with 1999 as the base year (Bureau of Labor Statistics).

Average daily workday slaughter by month was computed by using daily federally inspected hog slaughter collected from the *Livestock Marketing Information Center*. Aggregated monthly head slaughter was divided by the number of non-weekend, and non-holiday, slaughter days during the month. The first utilization to capacity ratio ranged from 74% to 106% over the period, with an average of 92%. The second overflow proxy averaged 92%, but ranged from 59% to 134%. Pork cold storage stocks data was obtained from *Cold Storage* reports (USDA).

The processing and marketing cost index was computed as the simple average of the index of finished energy products and average wages paid to packing plant employees (Bureau of Labor Statistics).

The retail shift index was computed using national monthly average retail prices for pork chicken, ground beef, and steak (Bureau of Labor Statistics). Monthly annualized U.S. population and monthly annualized U.S. disposable income were obtained from the St. Louis Federal Reserve Bank. Per capita income was computed by dividing U.S. disposable income by U.S. population.

Results

Two separate models were estimated using equation 1. The two models differ only in the specification of the capacity utilization variable. The dependent variable was tested for stationarity using the basic or augmented Dickey-Fuller stationarity test and the lag order was determined by minimizing the Akaike Information Criteria. The Dickey-Fuller test statistic was -2.42 and the 10% critical value was -2.57. Therefore, the null-hypothesis of a unit root could not be rejected. Data were first differenced, and the first differenced price series was found to be stationary. The number of observations used in estimation was 227.

Model results are listed in tables 3 and 4 for model specification (a) and (b), respectively. For either model, the variables selected explained about 57% of the variation in the Iowa-Southern Minnesota live hog cash price over the January 1981 to December 1999 period. P-values are listed to indicate the significance level of the estimated coefficients. Elasticities for the statistically significant variables were computed at the mean value for the respective variable. Seasonal shift variables varied in significance.

As expected, an increase in average daily slaughter led to a price decline. Of particular interest is the demand flexibility level. For the current study, the price flexibility was estimated as -0.663 and -0.714 for models (a) and (b), respectively. These are not constant elasticities because the processing utilization variables are specified such that current month slaughter is a component of the variable. For model (a), the denominator of the capacity utilization variable is current month slaughter. Therefore, the total price flexibility is computed by summing the elasticties, which equals -0.967. For model (b), the total price flexibility is equal to -0.806. However, both of the values in the current study are less than half of values estimated in previous studies, e.g., Wohlgenant, or through simple algebraic relationships, e.g., Plain and Grimes. Previous studies have estimated the live hog price flexibility to have an absolute value magnitude of over two. However, previous researchers have used pork production in their models.[4] The current study separated production into slaughter and dressed weight. To make comparisons with previous studies the percentage change in slaughter required to obtain a one percent change in pork production was calculated, holding weight constant. A value of 2.45 was calculated as the percentage change in slaughter required to obtain a 1% change in production when holding average dressed weight constant. Thus, multiplying -0.967 and -0.806 by 2.45 yields approximate, at the mean, pork flexiblilities of -2.373 and -1.89, respectively. These pork flexibility estimates are consistent with previous studies and help validate the specification of the current study.

An increase in dressed weight had a negative and statistically significant impact on price only in model (a). A one pound increase in dressed weight led to a $0.42/cwt. decline in live hog price. During fall 1998, dressed weight averaged around 192 lbs., which is 7 pounds greater than during the four months prior to this period.[5] Using the coefficient on dressed weight, the 7 pound weight increase decreased live hog price by about $3/cwt. during this time. For the fall 1998 period, the $0.199/cwt. decrease in live hog price estimated for model (b) would have amounted to almost a $1.50/cwt. decline in live hog price.

The capacity utilization variable had a negative sign and was statistically significant in both models. However, the impact on live hog price was significantly different between the models. Model specification (a) indicates that a one percentage point increase in the ratio decreases live hog price by $0.226/cwt. Model specification (b) indicates that a one percentage point increase in the ratio decreases live hog price by $0.062/cwt. Using model specification (a) results for simulation, during Fall 1998 the capacity utilization value was 9.5 percentage points above the average. Thus, capacity constraints during Fall 1998 may have led to a $2.14/cwt. decrease in live hog price for model specification (a). For model specification (b), during Fall 1998 the capacity utilization ratio was 35 percentage points above the average. Thus, capacity constraints during Fall 1998 may have led to $2.17/cwt. decrease in live hog price for model specification (b). The values estimated here are considerably lower than the values estimated by Spivey et al.; however, the impacts estimated here would still be considered economically significant.

For neither model was the impact of a change in processing costs statistically significant in explaining variability in live hog price. This result may be due to the deflated live hog price and processing cost index being correlated. Also, changes in the processing cost index occurred slowly over the period of this study.

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[4] A simple model with live hog price as the dependent variable and pork production as the explanatory variable was estimated. The estimated live hog price flexibility was negative 2.74.
[5] The combination of low grain prices and low hog prices may have caused producers to hold hogs longer before slaughter.

The retail demand shift index was not statistically significant for either model specification. The low variability of this variable over the sample period may have had an impact.[6]

A one percentage point increase in the cold storage stock ratio was found to decrease live hog cash price by $0.149/cwt. for model specification (a) and $0.143/cwt. for model specification (b). Both variables were statistically significant. This result was as hypothesized. To quantify this result, the cold storage stock variable in fall 1998 was 10 percentage points higher than during fall 1997. This increase caused a $1.44/cwt. year-to-year decline in live hog price.

Time Path of Live Hog Flexibility

Flexible Least Squares was used to develop a graphical representation of the time path of the live hog price flexibility estimate over time. The FLS estimator was used to estimate the model specified in equation 1 for model specification (a) only. A benefit of the FLS estimator is that parameter flexibility allows for outlying data points due to structural change. Figure 2 plots the residual series for model specification (a) for the OLS and the FLS estimator. Clearly, during the most recent years the FLS estimator provides a more accurate in-sample forecast than OLS. This is important because it is difficult to appropriately specify the live hog demand model to capture the structural change and due to limited observations over a short time period.

Summary statistics of the flexible least squares estimator for the own-flexibility and capacity utilization coefficients are reported in table 5. Also, the time paths of the own flexibility and processing capacity utilization elasticity estimates, for 8=0.001, are graphed in figure 3. Figure 4 is the time path for the summation of the own-flexibility and processing capacity utilization coefficient over time, i.e., total own flexbility. The parameter estimates by themselves are of little value. The value of the FLS estimator is observing the change in magnitude of the coefficients over the period of study. As can be observed from either Figure 3 or Figure 4, the own-price flexibility remained fairly constant over the February 1981 to January 1994 period. Following the January 1994 period, the live hog flexibility increased (in absolute value) significantly, particularly during the fall 1998. Similarly, the capacity utilization elasticity estimate increased (in absolute value) substantially in fall 1994 and fall 1998. The FLS estimator indicates the magnitude of the capacity utilization estimate increased 800% in fall 1998. Thus, the impact on live hog price during fall 1998 due to processing capacity constraints could have been over $16/cwt. decline ($2.14/cwt x 8).

Figure 5 is used to illustrate the change in processor utilization to capacity, as specified in model (a). Over time, this variable has trended toward one. There has been considerable structural change in pork processing facilities over this time period. During the 1980s packers typically operated an 8 hour single-shift 5 day week, where packers could effectively increase capacity by 50% by moving to a 10 hour day and processing animals on Saturday. Because of

[6] To interpret these values the coefficients must be decomposed following Wohlgenant's procedures. Because the focus of this study does not directly pertain to the decomposition of this coefficient into cross-price and income effects, interpretation of this variable is foregone. The variable was included for proper model specification.

economies of size, packers shifted away from the traditional slaughter week. Now, packing facilities typically operate two processing shifts and a third shift used for clean-up. The processing capacity of most packing facilities can only increase by operating during the weekend. Thus, the capacity utilization component of the own-price flexibility may have become more variable since the mid 1990s because processors have less capacity flexibility.

Conclusions

Using monthly data from 1981 through 1999, inverse live hog demand models, employing two alternate pork processing capacity constraint variables, were estimated to investigate claims that that the live hog demand flexibility has increased in magnitude (absolute value). Results reveal that, when calculated at the mean of the 1981-1999 period, the impact of changes in pork production on live hog price were similar to those reported by previous researchers. However, results from Flexible Least Squares estimations indicate that the live hog demand has become much more inelastic since the mid-1990s, as the live hog demand flexibility increased nearly eight-fold from the mid-1990s to the late 1990s.

Results from this study have several important implications for the pork sector. First, the study indicates that live hog demand became more inelastic during the mid to late 1990's. As a result, modest changes in hog slaughter and pork production lead to relatively larger changes in barrow and gilt prices than just a decade ago. Second, this study demonstrates conclusively that high capacity utilization in the pork processing sector has had a negative impact on live hog prices. This was especially true in the fall of 1998 when slaughter increased to unprecedented levels during November and December. In fact, this study suggests that as much as $16 per cwt. of the 55% price decline observed from fall 1997 to fall 1998 might have been attributable to a reduction in processor capacity flexibility. Finally, live hog prices were also found to be responsive to changes in both average dressed weights and cold storage stocks. A review of these two factors impact on live hog prices during fall 1998 relative to fall 1997 indicates increases in both variables explained about $4.50 per cwt. of the year-to-year price decline.

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Table 1. Description of Variables Used in Live Hog Inverse Demand Model Specified in Equation 1 and Expected Impact on Live Hog Price.

Variable	Description	Expected Impact on Live Hog Price
Iowa - Southern Minnesota barrow & gilt cash price$_t$	Average price received by hog producers for a 48% lean animal in Iowa - Southern Minnesota cash market in month *t*	
Average daily slaughter$_t$	Average daily non-holiday slaughter during month *t*	(-)
Average dressed weight$_t$	Average dressed weight during month *t*	(-)
Processing utilization to capacity ratio$_t$	(a) Ratio of current month (*t*) non-holiday average daily slaughter to maximum month average daily slaughter during previous twelve months.	(-)
	(b) Ratio of non-holiday Saturday plus Monday average slaughter during the month relative to the maximum for that quarter in the year prior.	(-)
Index of marketing costs$_t$	Simple average of final energy product index and wage rate for packing plant employees during month *t*.	
Retail demand shift index$_t$	Summation of cross-elasticities of demand multiplied by the retail price of competing good, plus the income elasticity of pork multiplied by the sum of per capita income, plus population.	(+)
Cold storage stocks$_t$	Ratio of Pork cold storage stocks reported at the end of the month during month *t* to Pork cold storage stocks in month *t*-1.	(-)
Seasonality$_t$	Separate 0 or 1 binary variables for month (*default* = December)	(?)

Table 2. Summary Statistics of Variables used in Estimation of Live Hog Inverse Demand Model Specified in Equation 1 (Monthly data between January 1981 to December 1999).

Variable	Avg.	S.D.	Min	Max
Iowa - Southern Minnesota barrow & gilt cash price ($/cwt.)	46.04	8.30	13.92	63.46
Average daily non-holiday slaughter during month *t* (000 head)	343.58	33.46	268.84	432.49
Average monthly dressed weight during month *t* (lbs)	180.69	6.012	168.75	194.00
Processing utilization to capacity ratio				
(a) Ratio of current month (*t*) non-holiday average daily slaughter to maximum month average daily slaughter during previous twelve months.	92	5.47	74.47	106.37
(b) Ratio of non-holiday Saturday plus Monday average slaughter during the month relative to the maximum for that quarter in the prior year	92.38	15.47	59.15	133.50
Index of processing costs	166.95	16.10	136.74	193.39
Retail demand shift index	25.07	0.133	22.96	27.34
Cold storage stocks (million pounds)	326.71	82.19	175.06	595.23

Table 3. Estimation Results of First Difference Live Hog Inverse Demand Model (Dependent Variable is Live Hog Cash Price, $/cwt.).

Variable	Coefficient	p-value	Elasticity at the Mean
Average daily non-holiday slaughter	-0.114**	0.000	-0.633
Dressed weight	-0.421*	0.062	-1.222
Processing utilization to capacity ratio			
Ratio of current month (*t*) average daily slaughter to maximum monthly average daily slaughter during previous twelve months.	-0.226*	0.056	-0.334
Index of processing costs	-0.087	0.525	
Retail demand shift index	-0.560	0.135	
Cold storage stocks	-0.149**	0.000	-0.240
Seasonal shift variables (*default* = January)			
February	-3.832**	0.000	
March	-2.066*	0.071	
April	-0.207	0.845	
May	1.264	0.266	
June	-1.925	0.153	
July	-1.802	0.108	
August	-0.992	0.408	
September	1.329	0.327	
October	-2.485*	0.061	
November	-3.373**	0.009	
December	-2.112**	0.050	
Intercept	1.892**	0.034	
R – squared	0.563		
Mean of the Dependent Variable ($/cwt.)	-0.202		
No. of observations	227		

Note: One and two asterisk(s) represent coefficients significantly different from zero at the 10% and 5% level, respectively.

Table 4. Estimation Results of First Difference Live Hog Inverse Demand Model (Dependent Variable is Live Hog Cash Price, $/cwt).

Variable	Coefficient	p-value	Elasticity at the Mean
Average daily non-holiday slaughter	-0.129**	0.000	-0.714
Dressed weight	-0.199	0.386	
Processing utilization to capacity ratio			
Summation of non-holiday Saturday and Monday average slaughter during the month relative to the maximum from average slaughter during the same quarter in the prior year	-0.062**	0.005	-0.092
Index of processing costs	-0.087	0.523	
Retail demand shift index	-0.506	0.173	
Cold storage stocks	-0.146**	0.000	-0.135
Seasonal shift variables (*default* =December)			
January	-2.643**	0.016	
February	-0.610	0.574	
March	-0.033	0.975	
April	2.292**	0.044	
May	0.610	0.647	
June	-0.505	0.660	
July	1.249	0.280	
August	2.065	0.135	
September	-3.666**	0.009	
October	-2.192*	0.085	
November	-1.610	0.139	
Intercept	1.685	0.188	
R – squared	0.57		
Mean of the Dependent Variable ($/cwt.)	-0.202		
No. of observations	227		

Note: One and two asterisk(s) represent coefficients significantly different from zero at the 10% and 5% level, respectively.

Table 5. Summary Statistics of Flexible Least Squares Estimate for model (a).

	When Model Specification Includes:	
8	Own-Quantity Coefficient	Utilization to Capacity Coefficient
0.001	-0.118 (0.162)	-0.014 (0.333)
0.5	-0.118 (0.161)	-0.015 (0.331)
1	-0.115 (0.085)	-0.131 (0.010)

Note: Standard error in parenthesis

Figure 1. Monthly Average Nominal Iowa - Southern Minnesota Barrow & Gilt Live Hog Price and Monthly Average Daily Slaughter (February 1981 - December 1999).

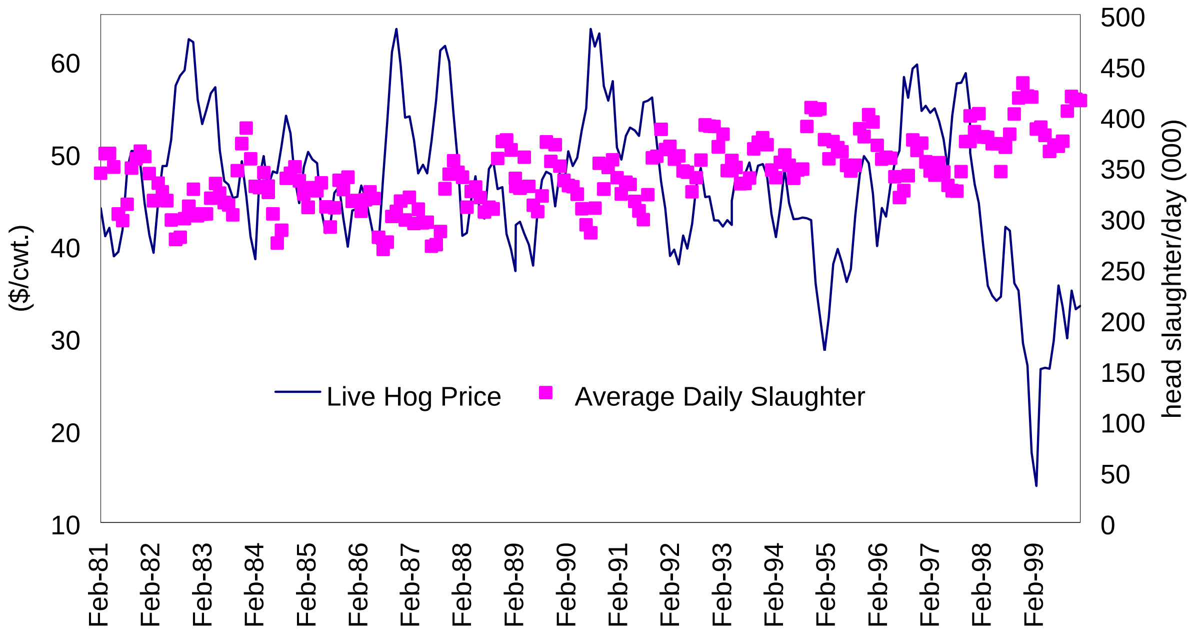

Figure 2. Plot of residuals from Live Hog Demand Model using OLS and Flexible Least Squares.

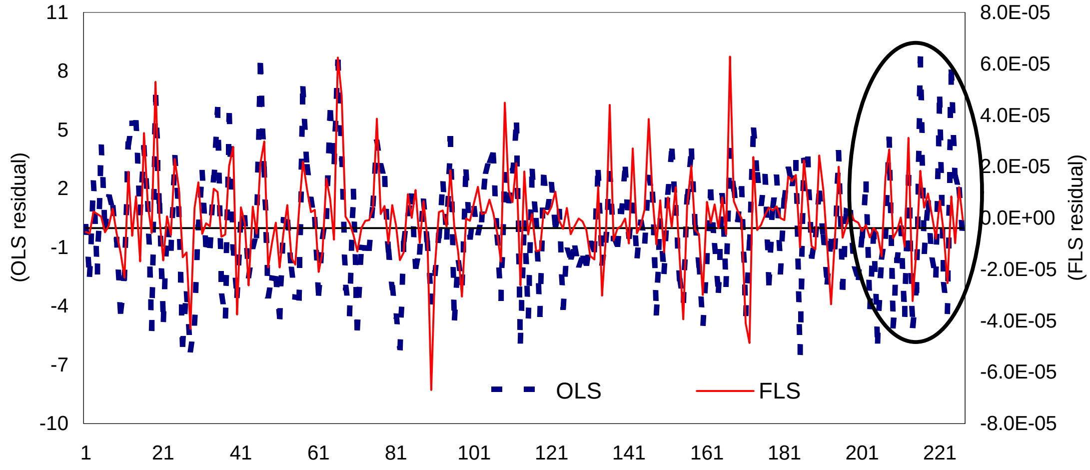

Figure 3. Time Path of the Pork Price Flexibility Coefficient for 8=0.001, for Model Specification (a), February 1981 - December 1999 (see description of model (a) in table 5).

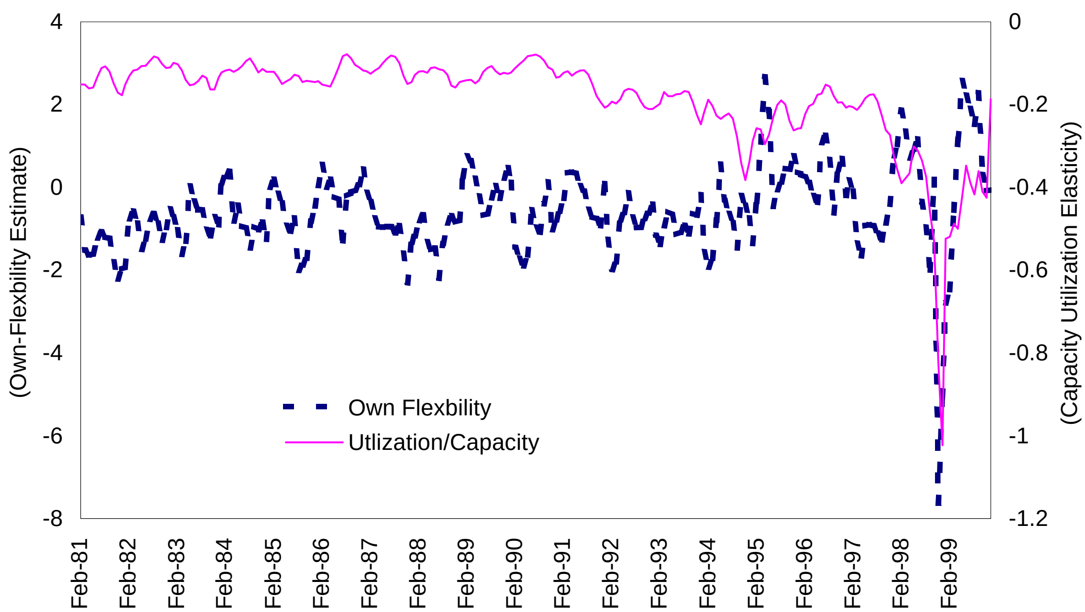

Figure 4. Total Time Path Pork Price Flexibility Coefficient for 8=0.001, for Model Specification (a), February 1981 - December 1999 (see description of model (a) in table 5).

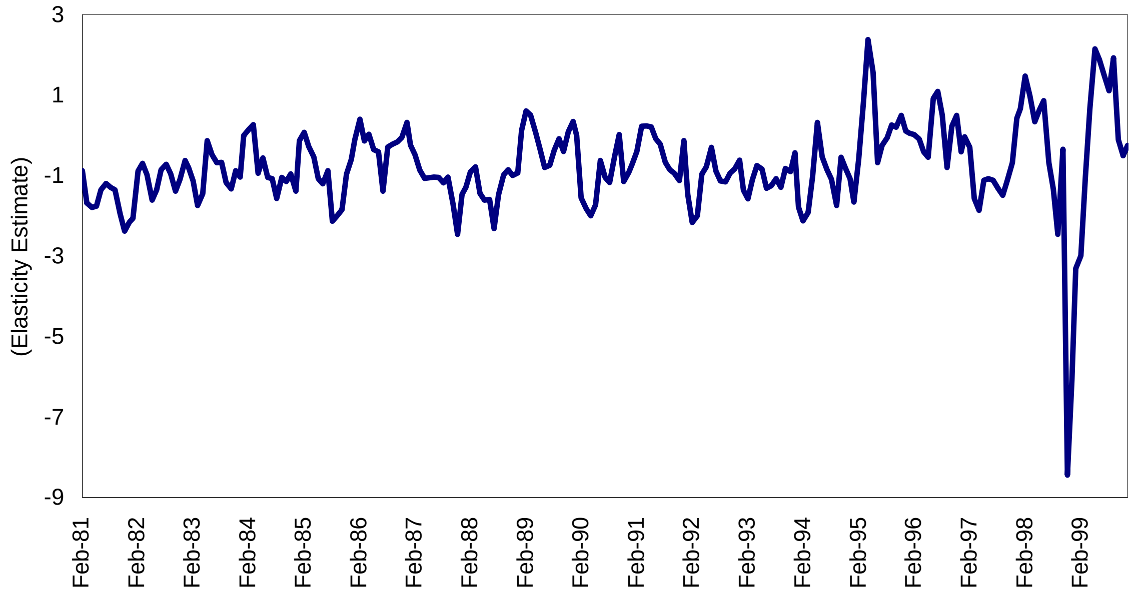

Figure 5. Processing Utilization to Capacity Specified as the Ratio of the Current Months Average Daily Slaughter to Maximum Monthly Average Daily Slaughter During the Previous Twelve Months (February 1981- December 1999).